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The National Ignition Facility Front-End Laser System Overview

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Abstract.

The National Ignition Facility (NIF) consists of a 192 beam high-energy glass laser system and target chamber, intended for inertial confinement fusion research. Each beam originates from the Front-End as a nominal 1.7 J, 20 ns pulse at . This temporally and spatially modulated pulse is injected into the main laser amplifier, boosted to 17.2 kJ, frequency tripled, and directed onto the fusion target. Advances in fiber oscillators and amplifiers, temporal modulation, diode and flashlamp-pumped rod amplifiers, and spatial beam shaping are required to successfully generate the laser pulse for NIF. In this paper, we present an overview of the Front-End laser system from the master oscillator to injection.

Each beam originates in one of four fiber ring oscillators which utilize polarization preserving Yb:SiO_2 single mode fibers. Since NIF requires four separate wavelengths separated by 10 Å, our oscillator was designed to be tunable over the four wavelengths centered around 1.054 μm. Tuning and mode control are accomplished using gratings and fiber mode control components. The ring oscillator is Q-switched to provide the maximum output power in a 20 ns pulse.

Spectral modulation is performed by an integrated electrooptic phase modulator, which adds up to 30 GHz of bandwidth to each of the four wavelengths. Each wavelength is amplified and divided into 48 individual fibers, one for each of the 192 NIF beams. Throughout the modulation and splitting, our fiber system is operating at peak power well above that found in commercial fiber systems. Peak power of up to 20 W must be accommodated in certain system components, especially the connectors and waveguide splitters. The final operation before the fiber pulses are distributed is temporal intensity modulation of each fiber pulse. Meeting target needs places a stringent temporal control requirement on beam intensity, including up to 500:1 contrast, 100:1 signal-to-noise over the entire pulse, and tight requirements on the time resolved intensity profile.

The main amplification stages for the Front-End laser are located in the preamplifier module (PAM) which is co-located with the main NIF beamlines. A fiber for each beam provides the highly formatted 500 pJ pulse to each PAM, where the energy is boosted to 10 mJ in a regenerative amplifier, and then to approximately 10 J in a four-pass flashlamp-pumped rod amplifier. The regenerative amplifier is designed to operate under minimal saturation to preserve the temporal pulse shape, and amplify the pulse by 10^7 with better than ±2% pulse to pulse repeatability. A pair of diode-pumped rods was chosen to accomplish this, in a unique regenerative amplifier configuration which minimizes the amplifier footprint while maximizing the rod gain. The gaussian beam from the regenerative amplifier is apertured to a square beam and spatially shaped to compensate for spatial gain variations in the main laser cavity. The final amplification stage, a four-pass flashlamp-pumped rod amplifier, boosts the square beam to approximately 10 J.

We will describe the Front-End laser system, and discuss experimental results to date on its components.

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